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ABSTRACT:

1496137 Seaming non-metallic sheet material KERRY ULTRASONICS Ltd 25 June 1975 [28 June 1974] 28729/74 Heading B5K In a method of welding plastics workpieces together by the application of ultrasonic vibrational energy by an ultrasonic transducer having a working face 21 which engages one of the workpieces, the amplitude of vibration of the working face 21 is monitored by detector means 22 providing an output signal proportional to this amplitude, the output signal is compared with an experimentally determined reference signal and the application of ultrasonic energy to the workpieces is interrupted when the difference between the output signal and the reference signal attains a pre-selected datum value. As shown in Fig. 1, the ultrasonic transducer comprises a pair of piezoelectric elements 10, 12 sandwiched between metallic bodies 14, 16 and having an operating alternating voltage applied thereto at terminals 13. A tapered horn 18 is secured to the body 16 and has a working face 21. The detector means 22 comprises a strain-sensitive pick-up, e.g. a secondary piezoelectric transducer, cemented to the horn 18 near the point of maximum stress. The output voltage V 1 generated by the transducer 22 when the apparatus is in use is available at terminals 19. A voltage comparator, Fig. 2 (not shown), compares the voltage V 1 with a preset reference voltage V 0 and the output (V 0 -V 1) is used to switch a transistor in the circuit of a relay having a pair of contacts connected between the terminals 13 and the power supply therefor. When (V 0 -V 1) becomes positive the transistor is rendered non-conducting so as to cause normally open contacts of the relay to open to cut off the power supply to the transducer. A time delay circuit prevents the relay dropping out inadvertently as a result of spurious brief signals. In modifications (not shown), the detector means 22 comprises an accelerometer or a displacement monitor or the ultrasonic transducer itself is included in a motional circuit attached to its terminals and capable of providing an output signal proportional to the transducer motion. The transducer is driven under either constant-current or constant-voltage conditions. It is necessary to calibrate the apparatus to establish the value of the reference signal applicable to any particular welding operation. Preferably, the apparatus is arranged so that power is not supplied to the ultrasonic transducer until the working face 21 is in pressure engagement with the workpieces.

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(54) WELDING PLASTICS WORKPIECES

(71) We, KERRY ULTRASONICS LIMITED, a British Company of Hunting Gate, Wilbury Way, Hitchin, Hertfordshire, SG4 0TQ, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of, and apparatus for, welding plastics workpieces together by the application of ultrasonic vibrational (mechanical) energy by means of an ultrasonic transducer having a working face which engages the workpieces.

In ultrasonic plastics welding, the time for which the ultrasonic energy requires to be applied to the workpieces may vary by up to ±15% (relative to the average time) in the performance of any one of a series of repetetive welding operations due to various factors such as dimensional variations in the workpieces themselves. At present, the normal procedure is to determine the longest weld time and control the application of power to the transducer by means of an electronic timer. However, this gives rise to appreciable over-welding of some components causing poor appearance and possibly deterioration of the weld. Also, the cycle time is longer than is strictly necessary so that throughput is not at an optimum.

According to the invention we provide such a method of welding plastics workpieces together by the application of ultrasonic energy by means of an ultrasonic transducer having a working force which engages one of said workpieces wherein the amplitude of vibration of the working face of the ultrasonic transducer is monitored by detector means providing an output signal proportional to said amplitude, and wherein the application of ultrasonic energy to the workpieces is automatically terminated when the weld is fully made by comparing said output signal with an experimentally determined reference signal, the arrangement being such that the application of the ultrasonic energy is interrupted when the difference between said output signal and said reference signal attains a predetermined datum value.

As the weld is progressively made the load on the transducer changes and the vibrational amplitude at the working face falls to a minimum value. In accordance with the invention it is this change of vibrational amplitude which is utilised to monitor the progress of the welding operation and to cut off the supply of ultrasonic energy as soon the weld is properly made. It will be understood that where, as is normal, the ultrasonic energy is applied for a predetermined period of time, this may sometimes be too short or to long due to the factors mentioned above. By monitoring the performance of the transducer it is, however, possible to determine the vibrational amplitude applicable at the completion of any given repetitive welding operation carried out under standardised conditions. In this way it is possible to establish experimentally for any given operation the value of the reference signal which may, for example, correspond to the output of the detector means equivalent to the minimum value of the vibrational amplitude of the working face of the transducer.

According to the invention we also provide ultrasonic welding apparatus of the kind including an ultrasonic transducer for generating ultrasonic vibrational energy and transmitting the same through a working face adapted to engage a plastics workpiece to be welded to another plastics workpiece, wherein detector means is provided to monitor the amplitude of vibration of the working face of the ultrasonic transducer and produce an output signal proportional to said amplitude, and means are further provided for comparing said output signal with a reference signal and interrupting the application of ultrasonic energy to the workpieces when the difference between

said output signal and said reference signal attains a preselected datum value.

The detector means may comprise a mechanical pick-up attached to the ultrasonic transducer. The mechanical pick-up may take the form of a strain sensitive pick-up, such as a piezoelectric transducer, or an accelerometer, or a displacement monitor. The output signal from any such pick-up, or secondary transducer, will be directly proportional to the vibrational amplitude of the working face of the ultrasonic transducer. Thus, during the performance of a welding operation, the output signal will decrease as the vibrational amplitude of the working face decreases towards the minimum value previously mentioned.

However, instead of using a secondary transducer in this way, it is alternatively possible to include the ultrasonic transducer itself in a motional circuit attached to its electrical terminals, capable of providing an output signal proportional to the transducer motion. For example, the circuit may take the form of a bridge network, a comparator or balancing network, or a so-called "bucking-transformer" or compensator. These "motional" circuits will be familiar to those skilled in the art.

Whether the detector means takes the form of a mechanical pick-up or a motional circuit, a voltage signal obtained, V_1, may be compared with a reference signal, V_0, to give a difference signal (V_0–V_1) which, when it becomes positive (or exceeds any pre-selected value) can be used to operate a switch to cut-off the power supply to the drive transducer.

Whatever form the detector takes, the signal changes will be greater if the ultrasonic transducer is driven under either constant-current or constant-voltage conditions. In the former case (where the impedance of the drive source is large compared with the driving-point impedance of the transducer) the voltage signal obtained will be proportional to the mechanical impedance of the transducer with its load. In the latter case (where the impedance of the drive source is small compared with the driving-point impedance of the transducer) the voltage signal obtained will be proportional to the mechanical admittance of the transducer with its load.

Whatever form the detector takes, it is necessary for the apparatus to be calibrated in order to establish the value of the reference signal applicable to any particular welding operation. For this purpose, the output signal may be displayed as a function of time using, for example, either a fast pen recorder, a storage oscilloscope or an oscilloscope with a long-persistence tube and slow time-base speed. From a graphical presentation of this information, it is then possible to determine the signal levels which correspond to the starting conditions and those which obtain when the weld is fully made.

The reference signal can be provided in any convenient manner. Conveniently, such reference signal is made substantially equal to the value of the output voltage, i.e. the output of the pick-up or the off-balance voltage of the bridge, when the weld is fully made. By the application of standard techniques, it is then possible to arrange that when the difference voltage (V_0–V_1) becomes positive, the difference signal is used to operate a switch to cut off the transducer supply.

Clearly, the reference signal will have to be determined for each different welding operation, but this is a relatively simple operation, and once it has been performed the apparatus can be used to repeat the same type of welding operation indefinitely, although it would be advisable to check the calibration of the apparatus from time to time.

Preferably the apparatus is so arranged that power is not supplied to the ultrasonic transducer until the working face is in pressure engagement with the workpiece in order to prevent the possibility of damage to the apparatus which might arise if the transducer were to be energised whilst not under load. Thus, in use, an operator merely requires to advance the transducer to engage the workpiece and this will automatically commence the welding operation, which in turn can automatically be terminated in the manner previously explained.

The invention will now be described by way of example with reference to the accompanying drawings wherein:—

Figure 1 is a diagram of an ultrasonic transducer in accordance with the invention,

Figure 2 is a block schematic diagram showing the arrangement of circuit elements employed in the detector associated with the ultrasonic transducer, and

Figure 3 is a graph showing a typical voltage signal as obtained from the detector.

Figure 1 shows an ultrasonic transducer of the sandwich type in which a pair of piezoelectric elements 10 and 12 are sandwiched between metallic bodies 14 and 16, the piezoelectric elements being maintained in a state of compression by means not shown but familiar to those skilled in the art. An operating alternating

voltage is applied to the piezoelectric elements by way of terminals 13.

A velocity transformer, or horn, 18 is firmly secured to the body 16, and this includes the usual tapering nose portion 20 having an end face 21 specifically designed to engage a workpiece. In the embodiment illustrated a secondary transducer 22, also comprising a piezoelectric element, is cemented to the horn 18 at a position near to the point of maximum stress. The output voltage V_1 generated by the secondary transducer 22 when the apparatus is in use is available at terminals 19.

As previously mentioned, other forms of mechanical pick-up could be substituted for the piezoelectric element 22 in all cases to provide the output voltage V_1.

The time dependence of the output voltage V_1 is shown in Figure 3 and it will be seen that when a welding operation is initiated at time t_s the value of the voltage V_1 falls towards a substantially constant minimum value.

By means of a voltage comparator (figure 2) the output voltage V_1 is compared with a preset reference voltage V_0 and the output $(V_0–V_1)$ is used to switch a transistor Tr in the circuit of a relay having a pair of contacts (not shown) connected between the terminals 13 for the ultrasonic transducers 10 and 12 and the power supply circuit therefor. The value of the reference voltage V_0 is adjustable and is set to be approximately equal to the final minimum value of voltage V_1. The arrangement is such that when the value of $(V_0–V_1)$ becomes positive the transistor Tr is rendered non-conducting so as to cause the normally open contacts of the relay to open. A time delay circuit is interposed between the voltage comparator and the transistor to prevent the relay dropping out inadvertently as a result of spurious brief positive signals.

Thus, at time t_F the relay is de-energised and the weld is completed in a time (t) which is dependant on the time actually taken for the output voltage V_1 of the secondary transducer 22 to fall from its initial value to the reference value V_0.

Alternatively, as previously mentioned instead of employing a secondary transducer 22, the output voltage V_1 can be derived from the voltage appearing at terminals 13 by means of a motional circuit.

WHAT WE CLAIM IS:—

1. A method of welding plastics workpieces together by the application of ultrasonic vibrational energy by means of an ultrasonic transducer having a working force which energises one of said workpieces wherein the amplitude of vibration of the working face of the ultrasonic transducer is monitored by detector means providing an output signal proportional to said amplitude, and wherein the application of ultrasonic energy to the workpieces is automatically terminated when the weld is fully made by comparing said output signal with an experimentally determined reference signal the arrangement being such that the application of the ultrasonic energy is interrupted when the difference between said output signal and said reference signal attains a predetermined datum value.

2. Ultrasonic welding apparatus of the kind including an ultrasonic transducer for generating ultrasonic vibrational energy and transmitting the same through a working face adapted to engage a plastics workpiece to be welded to another plastics workpiece, wherein detector means is provided to monitor the amplitude of vibration of the working face of the ultrasonic transducer and produce an output signal proportional to said amplitude, and means are further provided for comparing said output signal with a reference signal and interrupting the application of ultrasonic energy to the workpiece when the difference between said output signal and said reference signal attains a preslected datum value.

3. Apparatus according to claim 2 wherein the detector means comprises a mechanical pick-up attached to the ultrasonic transducer.

4. Apparatus according to claim 3 wherein the mechanical pick-up comprises a strain sensitive pick-up.

5. Apparatus according to claim 2 wherein said output signal is provided by a motional circuit attached to the electrical terminals of the ultrasonic transducer itself.

6. Apparatus according to any one of claims 3 to 5 wherein the ultrasonic transducer is driven under constant current conditions.

7. Apparatus according to any one of claims 3 to 5 wherein the ultrasonic transducer is driven under constant voltage conditions.

8. Apparatus according to any one of claims 2 to 7 wherein the reference signal is made substantially equal to the value of the output signal when the weld is fully made.

9. Apparatus according to claim 8 wherein the difference between said signals, when it exceeds a predetermined value, is used to operate a switch to cut off

the supply of ultrasonic energy to the ultrasonic transducer.

10. A method of welding plastics workpieces together substantially as hereinbefore described with reference to the accompanying drawings.

11. Ultrasonic welding apparatus substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

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FIG. 1.

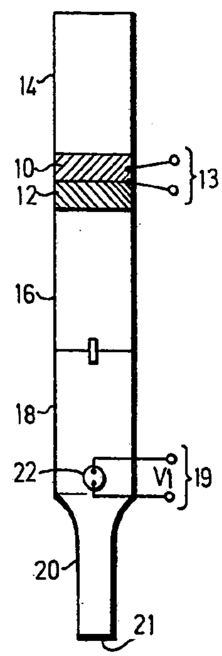

FIG. 2.

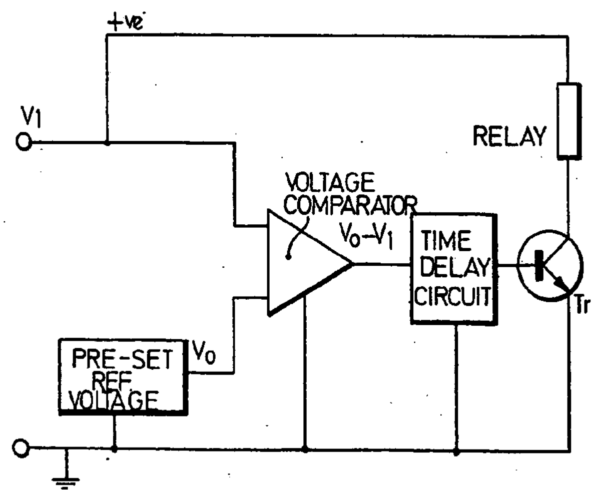

FIG. 3.